Dear Steve, Andrew, Mark, and Ian,

Thanks again for agreeing to participate in the Snowmass session titled "Dark Energy: Why Go Further?" next week. We have a little over 1.5 hours for the session, but much of it should be discussion.

The focus is to address the question often asked of dark energy surveys: when do you stop? Don't we already know it's lambda? If so, why keep on spending all this money on surveys.

Again, thanks for agreeing to do this.

Best,
Scott

Setting dark energy aside, a wide field optical survey is well-justified by the cartography, cinematography and photometry it will perform and the huge range of astrophysics it will address. (LSST as example:)

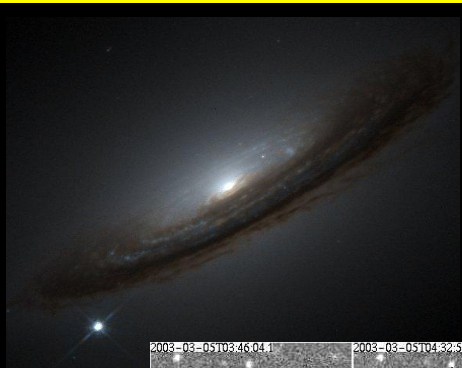
Dark Energy-Dark Matter

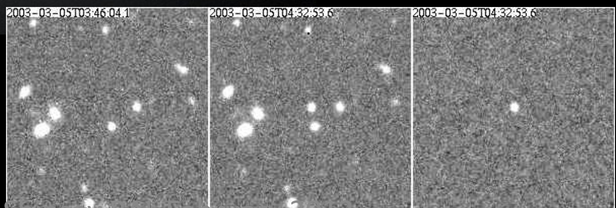
Multiple investigations into the nature of the dominant components of the universe

Inventory of the Solar System

Find 90% of hazardous NEOs down to 140 m over 10 yrs & test theories of solar system formation

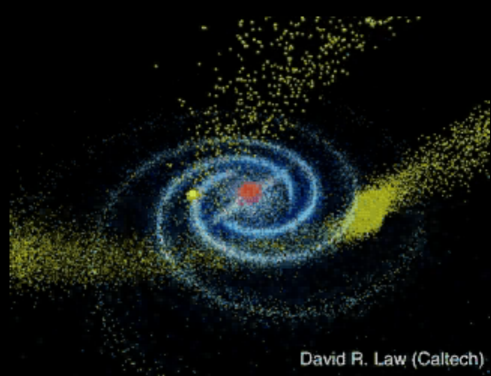
"Movie" of the Universe: time domain



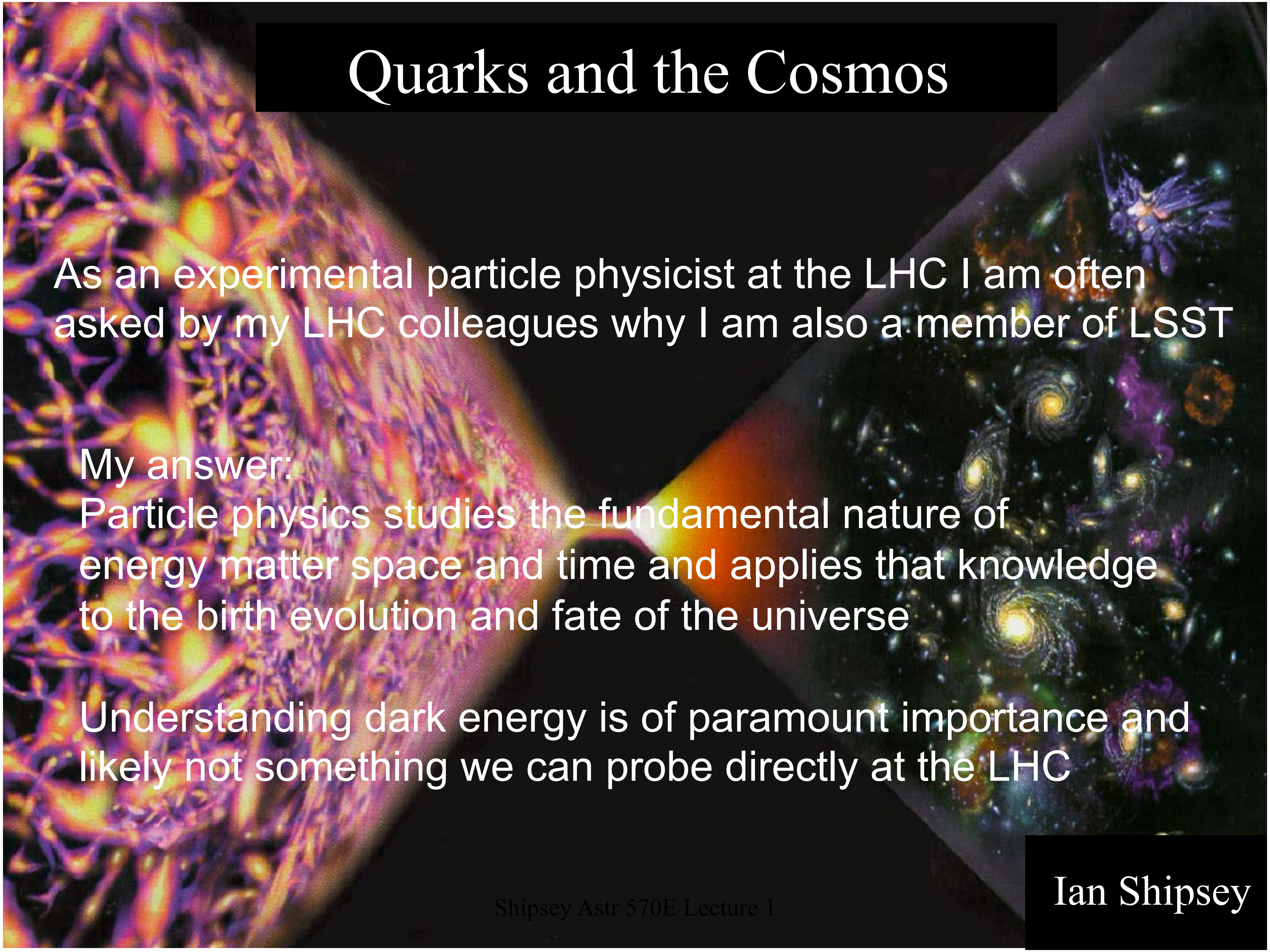


Discovering the transient & unknown on time scales days to years

Mapping the Milky Way



Map the rich and complex structure of the galaxy in unprecedented detail and extent



Quarks and the Cosmos

As an experimental particle physicist at the LHC I am often asked by my LHC colleagues why I am also a member of LSST

My answer:
Particle physics studies the fundamental nature of energy matter space and time and applies that knowledge to the birth evolution and fate of the universe

Understanding dark energy is of paramount importance and likely not something we can probe directly at the LHC

Ian Shipsey

Our science progresses by experimentation, observation, and theory

Nobody would have predicted that slight irregularities in black body radiation would have led to an entirely new conception of the world in terms of quantum theory

That pondering the constancy of the speed of light would have led to $E= mc^2$

That special relativity and quantum mechanics would have led to anti-matter

Experiments that explore uncharted territory, or study phenomena we do not understand with greater precision lead to a deeper understanding of nature

Precision is important but not always

Precision lead to the discovery of Neptune
Precision spectroscopy in the development of QED

Precision is justified when it can identify a flaw in theory, or when it results in new physical phenomena being discovered but not solely because an experiment is feasible.

The proton magnetic moment is known is 10 ppb improving it to 1 ppb would likely not gain any new insight

The muon lifetime is known to 1 ppm improving it further would likely not gain any new insight

Flaws in theory are easy to come by when a phenomenon is new physics improving the upper limit or observing $0\nu\beta\beta$, the edm of the electron, detecting CP violation in the neutrino sector and probing the equation of state of DE all qualify

A plethora of phenomena that require physics beyond the Standard Models

We have a remarkably successful Stanrdard Model of particle physics
We have a remarkably successful Standard Model of cosmology
But both are descriptions that contain ingredients we do not understand

The nature of the neutrino mass Dirac/Majorana CP
Flavor
What is the Higgs/ why that potentail and where does it come from?
Naturalness (hierarchy problem)   Unification of the forces
Baryon Asymmetry of the universe

Non baryonic Dark Matter
Dark Energy
Inflation
Gravity

Understanding these mysteriesare the next steps in obtaining a deeper understanding of nature. Appropriately a global program characterized by multiple facilities and multiple methods is planned to address each

Dark Energy: An unprecedented opportunity

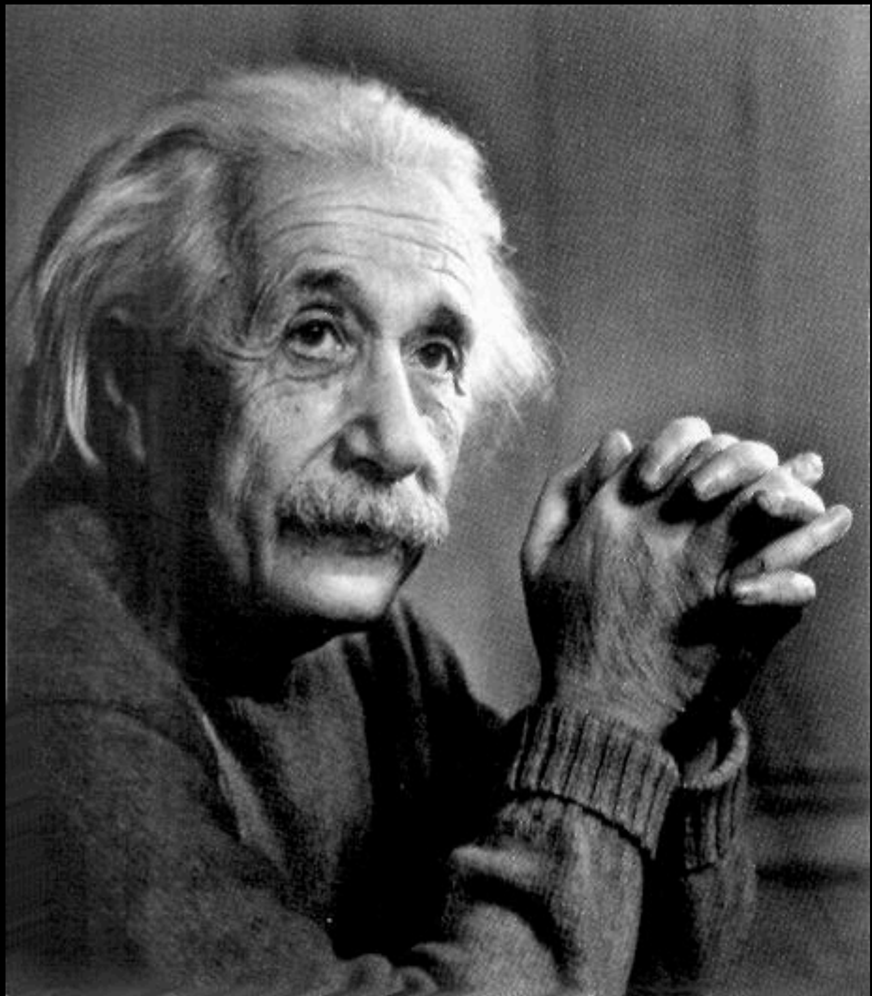
Either 72% of energy in Universe is of unknown origin, or General Relativity is wrong at large scales

Challenge: determine origin of Dark Energy or disprove GR

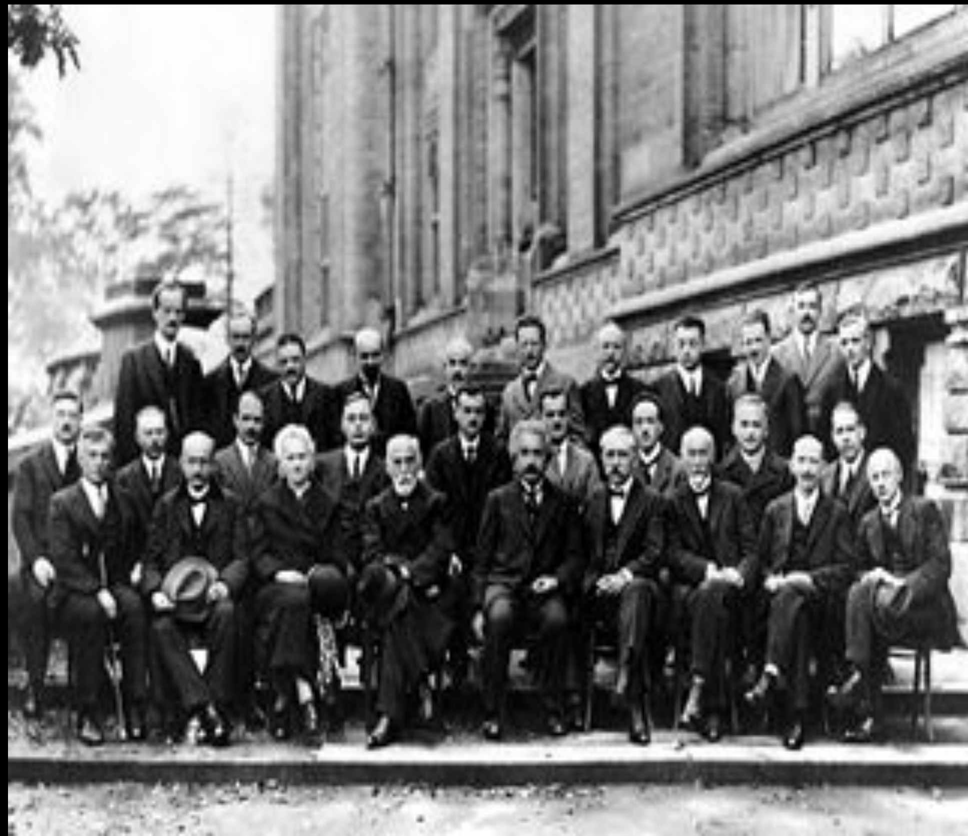
Approach: measure DE equation of state, w_0, and its evolution, w_a to the systematic limit with multiple probes

As a particle physicist and predating dark energy's discovery many of us were fascinated that the vacuum energy, or cosmological constant, is about 120 orders of magnitude smaller than naive estimates. If it was zero some principle or symmetry made it so. Now we know it is small but not zero the problem becomes harder. Perhaps it is the manifestation of a scalar field similar to the Higgs field but 44 orders of magnitude less massive, perhaps the field is dynamic or perhaps the value is a selection effect: our universe understood in terms of the multiverse., or GR needs revision.

Studying Dark Energy may bring the greatest prize in Physics within reach: reconciliation of the two great edificies



General Relativity

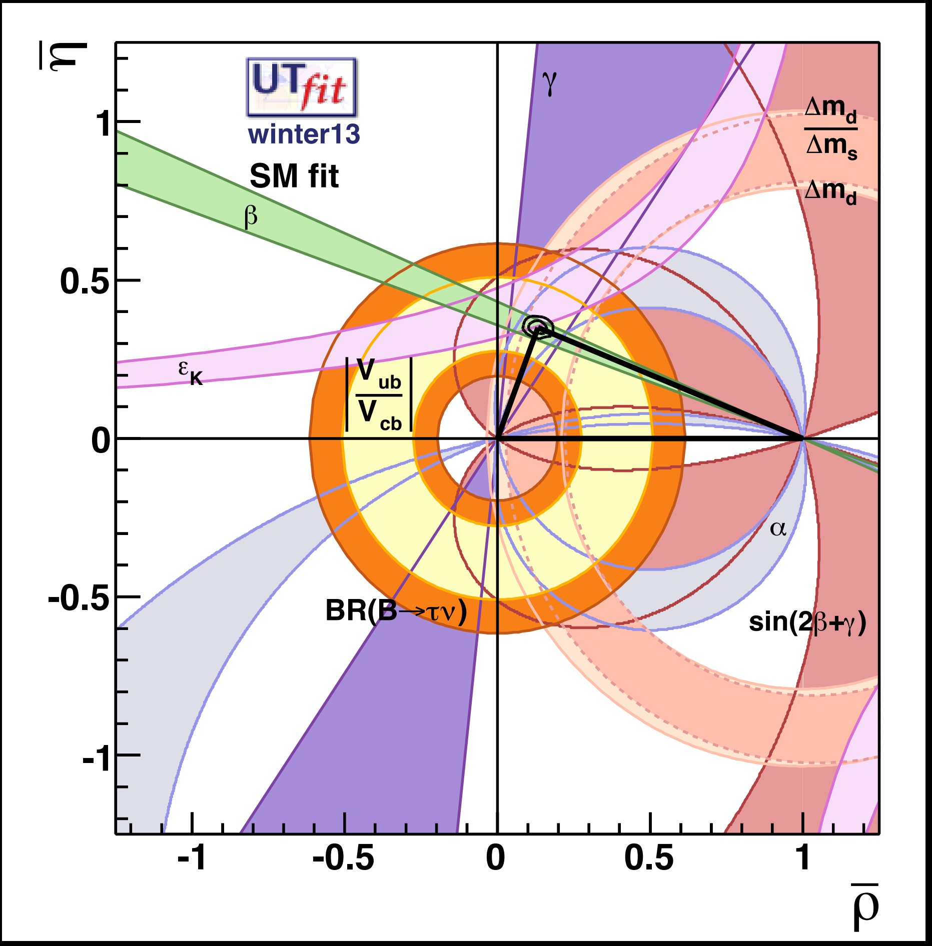


Quantum Mechanics

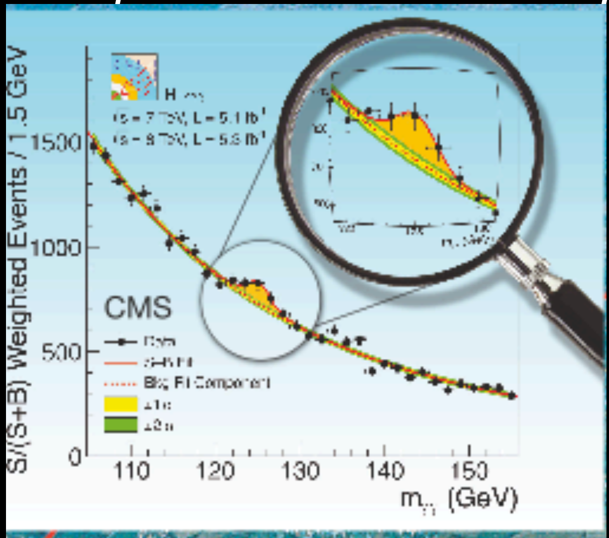
A program with multiple facilities, multiple probes and systematics limited measurements over several decades is something accelerator based particle physicists are used to and understand for *example the rewarding journey of quark mixing*

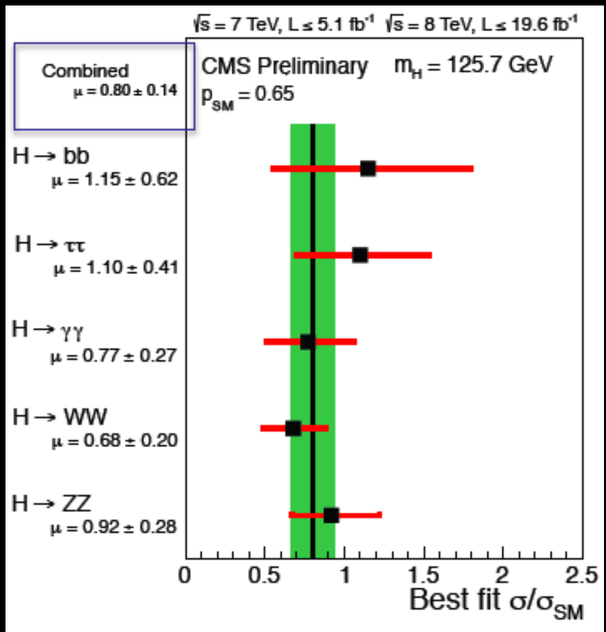
1964 discovery of indirect CP violation in Kaons (QM mixing)
1980 Nobel
1988-1999 Direct CP violation established in kaon decay (strange quark system)
2001 B Factories establish direct CP violation in beauty quark system
Numerous measurements with multiple probes in a world wide program
High degree of consistency high degree of redundancy
➔CKM theory established 2008 Nobel

Today a successful description of quark flavor mixing. However flavor remains a deep mystery more experimental data both from experiments studying quark flavor mixing, leptons and the energy frontier is needed.



Consistency of the various CKM parameter measurements demonstrates success of CKM theory *the journey to understand the Higgs will be similar, multiple facilities multiple probes. The very existence of an scalar particle and scalar field in particle physics is profound and has implications for inflation and dark energy*





Experimental particle physicists bring skills that are valuable

Instrumentation: design fabrication test and commissioning of large silicon arrays

Electronics

DAQ

big data

Systematics limited measurements and control of systematics

Experience organizing effective large distributed scientific collaborations